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[Micro wave plasma processing device and plasma processing method]

Author (K. Ogawa)

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Inventor	:	Muneo Furuse, Seiichi Watanabe, Takamitsu Kinsei
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(54). [Title of the invention]

Micro wave plasma processing device and plasma processing method

(57). [Abstract]

[Purpose]

By utilizing micro wave, the high density area of the plasma generated in a plasma processing chamber is suitably set up, thus, samples are subjected to high speed uniform processing.

[Structure]

Regarding a micro wave plasma processing device, resonator 24 that resonates the micro wave to a specified mode is mounted to the micro wave propagation means 2 that supplies to the plasma generating space 4 the micro wave generated by micro wave oscillator 1, and a wave guiding tube (26, 29) is mounted that gradually changes the opening cross section area from this resonator 24 up to the plasma generating space 4.

For the translation of figure 1, see in the back.

[Scope of the patent claims]

[Claim item 1]

Regarding the micro wave plasma processing device in which micro wave oscillated by a micro wave oscillator is guided to the plasma generating space via a micro wave propagation means, the sample is processed using the plasma generated in the aforementioned plasma generating space utilizing said micro wave,

The characteristics of the micro wave plasma processing device is that aforementioned micro wave propagation means is equipped

with the resonator that enables micro wave that propagates said means to be resonated with a specified mode, and the wave guiding tube in which the opening cross section area of the space from aforementioned resonator up to the aforementioned plasma generating space gradually change in the propagation direction of the aforementioned micro wave.

[Claim item 2]

Regarding the description in claim item 1, a micro wave plasma processing device wherein aforementioned wave guiding tube side of aforementioned resonator is made to be a slit plate.

[Claim item 3]

Regarding the description in claim item 1, a micro wave plasma processing device wherein the bore cross section area of aforementioned wave guiding tube decreases gradually in the propagation direction of aforementioned micro wave, thus, changes.

[Claim item 4]

Regarding the description in claim item 1, a micro wave plasma processing device wherein the bore cross section area of aforementioned wave guiding tube expands gradually in the propagation direction of aforementioned micro wave, thus, changes.

[Claim item 5]

Regarding the description in claim item 3 or 4, a micro wave plasma processing device wherein the bore cross section area of aforementioned wave guiding tube is changed step like.

[Claim item 6]

Regarding the description in claim item 1, a micro wave plasma processing device wherein the bore of aforementioned plasma generating space side of aforementioned wave guiding tube is made to be approximately same as the aforementioned wave guiding tube side inner diameter inside the chamber that forms the aforementioned plasma generating space.

[Claim item 7]

Regarding the description in claim item 1 or 3, a micro wave plasma processing device wherein the bore of aforementioned plasma generating space side of aforementioned wave guiding tube is made smaller than the aforementioned wave guiding tube side inner diameter inside the chamber that forms the aforementioned plasma generating space.

[Claim item 8]

Plasma processing method wherein micro wave is propagated by being turned into a specified mode and also, propagation area is gradually changed against the progress direction of micro wave, thus, is introduced into the plasma generating area, and using said micro wave, processing gas is made into plasma, thus samples are processed.

[Claim item 9]

The characteristics of Plasma processing method is that plasma density is high in the peripheral part on the wafer and plasma density is lower in the center part, and by raising resist selectivity, the material to be etched under resist mask is

subjected to etching processing.

[Claim item 10]

The characteristics of Plasma processing method is that regarding plasma with the electron density of 1×10^{11}/cm3 or more, the plasma density in the peripheral part on the wafer is higher than the center part, and samples are processed.

[Detailed explanation of the invention]

[0001]

[Utilized field in industry]

The present invention relates to the micro wave plasma processing device and plasma processing method, particularly to the micro wave plasma processing device and plasma processing method wherein etching to the wafer, plasma processing of film forming and the like are done with high speed and uniformly.

[0002]

[Prior arts]

Regarding the traditional micro wave plasma processing device, for instance, as described in Semiconductor plasma process technology (T. Sugano, editor, published by Industry Library (1980), P 139), quarts electric discharge chamber is formed inside of wave guiding tube that propagates micro wave and by the interaction of magnetic field generated by coils positioned outside of discharge chamber and the electric field of micro wave, plasma is generated in the discharge chamber, and using said plasma, plasma processing is applied on the surface of

semiconductor wafer.

[0003]

[Problems the present invention attempts to solve]

Regarding micro wave plasma processing device, the micro wave oscillated from a magnetron is introduced into plasma processing chamber via micro wave guiding tube, for instance, etching processing chamber, then, the energy of micro wave introduced into etching processing chamber is efficiently supplied for plasma in the electron cyclotron resonance (ECR) area mainly, high density plasma is supplied into the etching processing chamber and high density plasma is generated inside the etching processing chamber. And, the plasma generated inside etching processing chamber is transported to the wafer side where etching processing is done along the magnetic line formed inside etching processing chamber. Because of this, in order to uniformly execute etching processing of wafer, it is necessary that plasma density on the wafer where plasma processing is done is uniformly distributed as large area as possible, furthermore, in order to make the distribution of plasma on wafer uniformly, the mode of micro wave introduced into etching processing chamber be made uniformly.

[0004]

Regarding micro wave plasma processing device of above described prior arts, the micro wave guiding tube that introduces micro wave into etching processing chamber is made with the fixed bore diameter in order to transmit the micro wave by a specified mode,

and the bore diameter or the shape of the wave guiding tube was not changed.

[0005]

On the other hand, in order for micro wave to progress while the mode of the micro wave that passes inside the wave guiding tube is kept fixed, it is known that the wave guiding tube was used in which the bore diameter of the wave guiding tube of micro wave up to the etching processing chamber is gradually expanded.

[0006]

In case an attempt is made to generate high density plasma using these traditional micro wave guiding tubes, convex shaped plasma density distribution was generated where the center part of etching processing chamber has high density, hence, it was not possible to obtain high density uniformly distributed plasma.

[0007]

Hence, traditionally, in order to process wafer as fast and uniformly as possible, the center part vicinity was used where plasma density was high and plasma density was uniform comparatively, however, the uniformity of the entire wafer were insufficient. Hence, in case of the wafer processing with a large bore diameter of 8 inches or more, the plasma density in the wafer peripheral part was furthermore down, hence, etching rate slowed down compared with the wafer center part, hence making it difficult to uniformly etch the entire wafer. And in order to uniformly etch the entire wafer, it is necessary that the inner diameter of etching

processing chamber is made larger, and the high plasma density area in the center part be widened, thus posing the problem of making the device larger.

[0008]

In order to make the plasma on wafer high density, it is necessary that raising the power of incoming micro wave into the etching processing chamber and efficiently propagating the micro wave inside micro wave guiding tube be made compatible. Particularly, if there are surfaces that orthogonally intersect against the progress direction of micro wave on the way of micro wave guiding tube, the micro wave is reflected on this surface, the energy of the micro wave against plasma can not be transmitted efficiently. In case the transition efficiency of the energy of micro wave deteriorates, it copes by increasing the supply of the micro wave power traditionally, but it can not be said that plasma density was raised efficiently.

[0009]

The purpose of the present invention is executed to solve the problems of above described prior arts, and is to provide micro wave plasma processing device and plasma processing method whereby plasma high density area generated inside the plasma processing chamber can be set up, and samples are processed with high speed and uniformly.

[0010]

[Means to solve the problems]

Regarding micro wave plasma processing device, the above described purpose is attained by the following method: micro wave propagation means supplies micro wave generated by micro wave oscillator to the plasma generating space, and on this micro wave propagation means is mounted the resonator that enables micro wave to resonate with specified mode, wave guiding tube is mounted to this device that gradually changes the bore cross section area(opening diameter) from this resonator up to the plasma generating space, thus, micro wave is propagated by setting into a specified mode, and also, and is introduced to the plasma generating area by gradually changing the propagation area against the progress direction of micro wave, then, using said micro wave, processing gas is made into plasma, thus samples are processed,

[0011]

And, the bore on the plasma generating space side of the wave guiding tube is made smaller than the inner diameter of the wave guiding tube side inside of the chamber that forms plasma generating space, thus, obtaining the high density plasma in the peripheral part.

[0012]

[Actions/operations]

The resonator that resonates the micro wave with a specified mode is mounted on the way where micro wave generated by micro wave oscillator is supplied to the plasma generating space, and, by gradually changing the bore cross section area from this resonator

up to the plasma generating space, the mode of micro wave to be introduced into plasma generating space can be set up to the desired mode. For instance, the micro wave of TE01 mode that has the ring shaped strong electrical field intensity of the desired intensity (diameter direction) in the cross section in the progress direction of micro wave can be supplied to the plasma generating space. Thereby, the plasma can be generated that has the ring shaped high density plasma distribution on the ECR surface, and due to the plasma dispersion from ECR surface to the sample side, plasma distribution is obtained in which on the sample, middle high (convex shape) plasma distribution is changed to peripheral high (convex shape) plasma distribution, thus improving the uniformity, thus, in dealing with sample processing, processing is done under optimum plasma distribution, thus, samples are processed fast and uniformly.

[0013]

The bore on the plasma generating space side (opening diameter) of the wave guiding tube of micro wave that comes into plasma generating space is made smaller than the inner diameter of the wave guiding tube side of the chamber that forms the plasma generating space, thereby, micro wave once supplied into the chamber that forms plasma generating space can be designed not to escape from the chamber by reflections and the like, furthermore, high density plasma can be obtained in the periphery part.

[0014]

[Embodied examples]

The following will explain one embodied example of the present invention using figure 1 through figure 3. Figure 1 is a longitudinal cross section drawing of the micro wave plasma processing device. Symbol 1 is a magnetron which is a micro wave oscillator, for instance, it oscillates micro wave of 2.45 GHz. Symbol 2 is the micro wave propagation means for propagating micro wave that oscillated from magnetron 1, and in this case, the configuration is that rectangular wave guiding tube 21, disk shaped rectangular wave guiding tube 22, disk shaped wave guiding tube 23, resonator 24 and reduced wave guiding tube 26 are connected to magnetron 1 sequentially. Regarding rectangular wave guiding tube 21, it is set up with the size that propagates the micro wave of rectangular shaped TE11 mode on the. It has the interface 27 in order to match with the impedance of micro wave on the way. Disk shaped wave guiding tube 23 is set up with the size that propagates the micro wave of circular shaped TE11 mode in this case. Resonator 24 is equipped with slit plate 25 between the reduced wave guiding tube 26 and this, and in this case, as shown in figure 2, multiple slit holes are formed that are positioned radially. Resonator 24, in this case, is set up so as to oscillate micro wave of TE01 mode and also, to radiate micro wave of TE01 mode from slit plate 25. Reduced wave guiding tube 26 has, in this case, tapered inner surface so as to gradually reduce the bore

cross section area against the progress direction of micro wave. Regarding the tapering shape of reduced wave guiding tube 26, in this case, the incoming bore diameter of micro wave is approximately same as the inner diameter of resonator 24, and the exit diameter of micro wave is approximately same as the incoming bore diameter of the micro wave introduction side of plasma processing chamber 4 (later described).

[0015]

Symbol 4 is the chamber that forms plasma generating space, and in this case, is the plasma processing chamber that combines the plasma processing. Plasma processing chamber 4 is an electrically conductive body. And it is made of, for instance, highly pure aluminum and the like, and its inner surface is subjected to hard alümite processing and the like, and also plays the role of wave guiding tube of micro wave. Plasma processing chamber 4 is formed by setting up quarts plate 3 between reduced wave guiding tubes 26 and this; thus, the space on the reduced wave guiding tube 26 sides and the space inside processing chamber are separated. Plasma processing chamber 4 is connected by communicating with vacuum chamber 5. And at the bottom of vacuum chamber 5 is supported the sample table 8 via electrically insulating material. Sample table 8 is inside the space formed by plasma processing chamber 4 and vacuum chamber 5 and is a sample. IN this case, the positioning surface of wafer 10 is set up facing the quarts plate 3.

[0016]

In vacuum chamber 5, in this case, is provided the gas supplying means 12 that can uniformly supply the processing gas for processing film forming or etching from the periphery of the inner surface of top part of etching processing chamber 4, and also, vacuum exhaust means 11 is connected that can decompress the inside of vacuum chamber 5 to the specified pressure and exhaust. On sample table 8 is the power source for applying bias voltage for sample table 8. For instance, high frequently power source 9 is connected. Symbol 28 is the gate valve that sections off the vacuum chamber 5 and is connected to plasma processing chamber 4 and constitutes processing chamber.

[0017]

Outside of a resonator 24, a reduced wave guiding tube 26 and an etching processing chamber 4, solenoid coil 6, 7 is wound to form the magnetic field inside etching processing chamber 4. Regarding the device of the present invention, solenoid coil 6 can generate stronger magnetic field compared with the solenoid coil 7, and it is configured to be synthesized with the magnetic field of solenoid coil 7, and flat ECR surface is formed inside etching processing chamber 4.

[0018]

Regarding the micro wave plasma processing device with above described configuration, micro wave generated from magnetron 1 is guided to resonator 24 via rectangular wave guiding tube 21,

an interface 27, a disk shaped rectangular conversion wave guiding tube 22, and disk shaped wave guiding tube 23. The micro wave guided into resonator 24 resonates to the mode of specified micro wave inside and, is guided to the reduced wave guiding tube 26 via slit plate 25 released by said specified mode. The micro wave that passed reduced wave guiding tube 26 is guided inside etching processing chamber 4 via quarts plate 3. The micro wave guided into etching processing chamber 4 interacts with the magnetic field formed inside the etching processing chamber and turns the processing gas inside plasma processing chamber 4 into plasma. At this time, micro wave generated from magnetron 1 is introduced into the etching processing chamber 4 via resonator 24 of micro wave and reduced wave guiding tube 26, thus, density and distribution of plasma generated in etching processing chamber 4 turns into plasma whose testing result was that density and distribution are improved and its density is high and uniformly distributed.

[0019]

Figure 3 shows the result that measured the distribution of the ion current density of the plasma that comes onto the sample table (electrode) by the existence or non-existence of resonator 24 or the existence or non-existence of reduced wave guiding tube 26. In this case, this test result is that hot resist is used as a mask, and mixed processing gas of BCI3/ Cl2 is used for etching Al film. Regarding etching by this device, the conditions are:

processing pressure: 5~ 50 mTorr, processing gas flow amount: 50~300 ml, processing gas micro wave ratio: 0.5~1.5 (BCl_3)/1 (Cl_2), high frequency power source output: 25~250W, micro wave output: 200W~ 1.5 KW. Curve A shows the ion current density distribution in case resonator 24 and reduced wave guiding tube 26 are set up. Curve B shows the ion current density distribution in case resonator 24 and reduced wave guiding tube 26 are not set up. Curve C shows the ion current density distribution in case resonator 24 and reduced wave guiding tube 26 are not set up.

[0020]

According to figure 3, in case of the prior art that does not have resonator 24 and reduced wave guiding tube 26 set up, as shown in Curved line C, the ion current density in the center part of sample table is high, and that at periphery part of sample table is small, the ion current density on the sample table is not uniform, that is, plasma density on the sample table 8 inside plasma processing chamber 4 is not uniform, as one can tell clearly. When etching processing is done under such plasma condition, particularly resist selectivity in the center part of wafer was small, and in case the Al film with step like configuration was etched, and at the thin part of the resist film of stepped part, the chip part in the wafer center part was subjected to fast etching removal than the chip part in the periphery part of wafer, consequently, the problem was that the shape to be etched in Al film at the stepped part was not_retained.

[0021]

And in case resonator 24 is set up but reduced wave guiding tube 26 was not set up, as shown in curved line B, ion current density in the sample table center part decreases somewhat, however, the ion current density in the periphery part of sample table goes up, ion current density uniformity has improved in the entire surface of sample table, that is, the uniformity of the plasma density on the sample table 8 has improved, one can tell. It is speculated that the reason is that by resonator 26 with slit plate 25, micro wave with ring shaped strong electrical field intensity distribution mode, in this case, TE01 mode is specified, thus said micro wave is guided to plasma processing chamber 4, thereby, this produced the ring shaped strong plasma density distribution on ECR surface, thus, said plasma is dispersed heading toward the wafer. If the etching processing is done under such plasma condition, the difference of the resist selectivity between etching wafer center part and periphery part improves considerably, the uniformity vis-à-vis resist selectivity improves, thus improving the above described problems. And at this time. And, it did not impact on the etching uniformity of Al film.

[0022]

Furthermore, in case of said embodied example with resonator 24 and reduced wave guiding tube 26 provided, one can tell that while maintaining the uniformity of curved line B as shown in curved

line A, the ion current density improves in the entire surface of sample table, that is, high density plasma with increased plasma density can be generated with improved uniformity on the sample table 8. When etching is done under such plasma condition, wafer processing uniformity and processing speed can be improved respectively.

[0023]

As described above, by mounting the resonator 24 at the part of wave guiding tube of micro wave propagation means, the uniformity of ion current density on the sample table improves, furthermore, by setting up the reduced wave guiding tube 26 between the etching resonator 24 and quarts plate 3, while maintaining the distribution condition of ion current density on the sample table somewhat uniformly, the value of ion current density is increased. That is, the plasma on the sample table can be improved uniformly by high density. Thereby, when etching or film forming processing and the like is done, processing speed can be improved, and also, wafer 10 can be processed uniformly.

[0024]

Next, the second embodied example of micro wave plasma processing device of the present invention will be explained by figure 4. Figure 4 shows micro wave propagation means of the device in figure 1 and its plasma processing chamber part, and other than the members shown by same symbols and drawings of this figure, they are same as the members shown in figure 1, and its explanation

is omitted. The point of difference between this figure and figure 1 is that regarding the reduction wave guiding tube that is set up at the later step of resonator 24 (vis-a-vis the progress direction of micro wave) and guides the micro wave to etching processing chamber 4, reduced wave guiding tube 26a is used in which the bore diameter that arrives at the plasma processing chamber 4 side of said wave guiding tube is decreased step wise. In this case, vis-a-vis the wave length of micro wave that passes through reduced wave guiding tube 26a, the degree of decrease of bore diameter of reduced wave guiding tube 26a of micro wave is step wise decreased such that it can be ignored. By using such configuration, same effect as the aforementioned first embodied example can be obtained. If reduction wave guiding tube is used in which the bore decreased step wise, as is described above, donut shaped disk plates with different bores can be stacked up, reduced wave guiding tube 26a can be structured simply, thus enabling to modify the shape of reduced wave guiding tube 26a simply.

[0025]

Next, the third embodied example of micro wave plasma processing device of the present invention will be explained by figure 5. Figure 5 shows micro wave propagation means of the device in figure 1 and its plasma processing chamber part, and other than the members shown by same symbols and drawings of this figure, they are same as the members shown in figure 1, and its explanation is omitted. The difference between this figure and figure 1 is

that this uses reduced wave guiding tube 26b wherein the bore of plasma processing chamber 4 side of reduction wave guiding tube is made smaller than the micro wave introduction part of etching processing chamber 4. By doing like this, in the periphery part of wafer 10 particularly, the ion current density was furthermore raised than that of aforementioned device in figure 1.It is speculated the reason is that it is difficult to discharge the micro wave into the outside of plasma processing chamber 4 via quarts plate 3 from the inside of plasma processing chamber in reverse wherein said micro wave was once introduced into plasma processing chamber 4 via reduced wave guiding tube 26b and quarts plate 3.

[0026]

And, the aforementioned curved line shape in figure 3 changes depending on the processing gas used. That is, that is because the ion current density changed by processing gas, however, the distribution tendency of ion current density has the tendency similar to that shown in figure 3 regarding the relationship of the existence or non-existence of an oscillator, existence and non-existence of a reduced wave guiding tube, the size of the plasma processing chamber side bore of reduced wave guiding tube. hence, as described above, an oscillator and a reduced wave guiding tube are set up at micro wave propagation means and the bore of plasma processing chamber 4 side of reduced wave guiding tube are adjusted, thereby, the high density area of plasma on the wafer

can be formed at a desired position, thus, optimum plasma condition for etching or film forming processing and the like can be generated. For instance, in order to make resist selectivity uniformly inside of the wafer surface, the plasma density in the upper part of wafer is raised in the periphery part than the center part.

[0027]

Next, the fourth embodied example of micro wave plasma processing device of the present invention will be explained by figure 6. Figure 6 shows micro wave propagation means of the device in figure 1 and its plasma processing chamber part, and other than the members shown by same symbols and drawings of this figure, they are same as the members shown in figure 1, and its explanation is omitted. The difference between this figure and figure 1 is that replacing reduced wave guiding tube 26, an expanded wave guiding tube 29 is used wherein the bore of the opening cross section in the wave guiding tube is gradually expanded toward the plasma processing chamber 4 side, that is, against the progress direction of micro wave. By doing like this also, the high density area of plasma formed inside of the plasma processing chamber 4 can be changed, thus obtaining the optimum plasma condition for processing samples.

[0028]

According to above described embodied examples, the micro wave with specified mode set up by an oscillator is introduced into

plasma processing chamber using a reduced wave guiding tube or an expanded wave guiding tube, thus, the high density distribution area of plasma can be changed from traditional middle high condition to the optimum position in the periphery part direction, thus creating the plasma condition optimum for processing samples, hence, samples are processed uniformly and fast.

[0029]

And when the bore of the plasma processing chamber 4 side of a reduced wave guiding tube and an expanded wave guiding tube in these aforementioned embodied example is suitably adjusted, for instance, regarding the part that corresponds to the inner surface of a reduced wave guiding tube, the plates made of electrically conductive body are rounded into a conic shape and its end parts are stacked up, to be configured to be slidable and the like, thus reduction or expansion wave guiding tube that can change the bore automatically can be adopted, thereby, plasma density distribution during processing can be adjusted, and in case of etching processing, during etching and during over-etching and the like, the shape of reduced wave guiding tube is changed, the plasma distribution is modified in order to improve the selectivity against resists or foundation, thereby, etching processing with furthermore better yield can be executed. And, the plasma distribution control during processing can be applied during film forming processing depending on the needs.

[0030]

The adjustment technique of these plasma distributions can be applied for etching processing of metal, gates and oxide film other than Al film, and can be applied for processing using micro wave plasma such as film forming processing and the like other than etching processing.

[0031]

In the device shown in figure 1, the magnetic field by solenoid coil 6, 7 is used to generate plasma, however, it can be applied for the devices that does not use magnetic field. In case the plasma electron density generated inside of plasma processing chamber has no magnetic field, if it attains 7×10^{10}/cm3 or more (in case of existing magnetic field, 1×10^{11}/cm3 or more), plasma has the reflection boundary surface of micro wave, and starts to reflect a part of incoming micro wave. At this time, between said boundary surface and slit plates, a big enough space is created such that it oscillates the micro wave, thereby, the energy of micro wave is transmitted to the plasma efficiently, thus plasma density is improved, hence, it is preferred that the size of reduction or expanded wave guiding tube is set up, taking into consideration of this point.

[0032]

Furthermore, in the device shown in figure 1, processing gas is supplied from the surrounding of inner surface of the upper part of processing chamber against the wafer, however, it can be supplied from the quarts window part facing the wafer, hence, the

device details can be changed suitably.

[Effects of the invention]

According to the present invention, at the micro wave propagation means that supplies micro wave into the plasma generating space is set up the oscillator that oscillates and radiates the micro wave of specified mode, and a wave guiding tube that gradually changes the bore cross section area from this oscillator up to plasma generating space, thereby, the high density area of plasma generated inside the plasma processing chamber can be suitably set up, thus producing the effect in which the plasma on the sample can be made into the optimum plasma condition against the sample processing, thus, the sample is uniformly processed.

[Simple explanation of the drawings]

Figure 1 is a longitudinal cross section drawing showing micro wave plasma processing device which is one embodied example of the present invention.

Figure 2 is a drawing showing the detail of the slit plate of the device in figure 1

Figure 3 is the drawing showing the relationship of the existence or non-existence of a reduced wave guiding tube of micro wave and an expanded wave guiding tube and ion current density distribution.

Figure 4 is the longitudinal cross section drawing showing the micro wave propagation means part of micro wave plasma processing device of the second embodied example of the present invention

Figure 5 is the longitudinal cross section drawing showing the micro

wave propagation means part of micro wave plasma processing device which is the third embodied example of the present invention

Figure 6 is the longitudinal cross section drawing showing the micro wave propagation means part of micro wave plasma processing device that is the fourth embodied example of the present invention

[Explanation of the symbols]

1... magnetron, 2... Micro wave propagation means, 3... Quarts plate, 4... Plasma processing chamber, 24... Oscillator, 26... 26a, 26b... reduced wave guiding tube,

29... expanded wave guiding tube

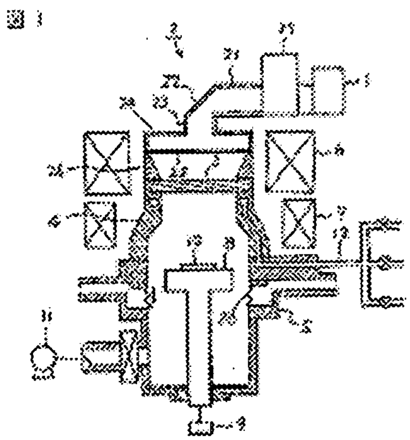

Figure 1

Figure 2

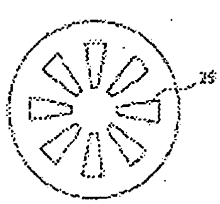

Figure 3

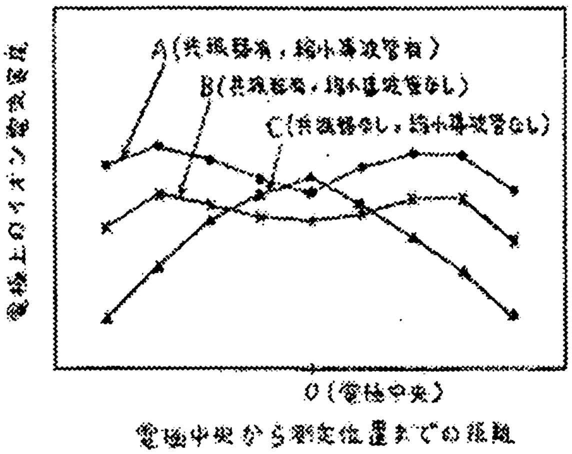

Figure 4

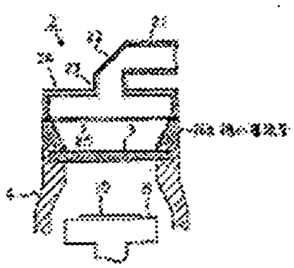

Figure 5

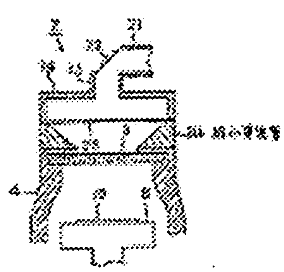

Figure 6